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# FATAL AND NON-FATAL ANOXIA INCIDENTS IN THE EIGHTH AIR FORCE DURING THE PERIOD 17 AUGUST 1942 TO 31 AUGUST 1944.

## I. INTRODUCTION.

### 1. Basis of Study.

The present study was initiated at the request of the Surgeon of the Eighth Air Force, Colonel Harry G. Armstrong, MC, in order to evaluate the cases of fatal and non-fatal anoxia occurring in operational aircraft and reported by the various organizations in the field. While there is evidence that there had been some mild cases during the first six months of operations in the Eighth Air Force, it was not until a death was reported in January 1943, that attention was more forcibly directed to this problem. The seriousness of the problem is indicated by the fact that in the two years of operations, from August 1942 through August 1944, there have been reported a number of deaths due to anoxia and a relatively larger number of non-fatal cases. As the scope and type of operations of the Eighth Air Force became more clearly defined, and the frequency of missions increased, it became possible to obtain more worthwhile information on the anoxia cases, thereby furnishing material for counter measures. All the reports that have come to the attention of this organization have emanated from the Group and Squadron Surgeons concerned. It is on these reports that this study is based.

### 2. Source of Data.

As mentioned above, this study is based on the report sent in by the Flight Surgeons of the organizations in which the incidents have taken place. While generally speaking, these reports have been satisfactory, too frequently essential data have been lacking. For example, in cases of freezing of oxygen masks, frequently no mention is made of the temperature, or incidents may be reported as due to "regulator failure" with no indication as to the nature of the failure, etc. It is evident that the flight surgeons often do not have the necessary basic technical knowledge, which could be obtained from the Group or Squadron Personal Equipment Officer. The inadequacies of some of the reports have necessitated liberal interpretation by the compilers of this study. In some cases it has been possible through follow-up in the concerned units, to determine the exact cause, but in many others the label "cause undetermined" has had to be applied. It is felt, however, that the general trends and conclusions are correct, as repeated personal checks have permitted amplification of otherwise unsatisfactory reports.

### 3. Correlation with Other Data.

It has been desirable to evaluate the rate of anoxic incidents in relation to sorties and in relation to mission experience. This has been made possible by data obtained through the Eighth Air Force Statistical Control and Operational Research Sections. The sortie figures cover the whole period from January 1943 through August 1944 but unfortunately crew mission experience is available only from 1 January 1944 on, so that in the comparison of the mission experience for aircrews and the mission experience at the time of the anoxia incidents, it has been necessary to neglect all the cases which occurred in 1943.

4. Other Analyses.

Other analyses have been carried out, particularly on the importance of position in aircraft on the incidence of anoxia. It must be noted here that no difference is made between B-17 and B-24 aircraft as the reports often do not specify the type of aircraft, and furthermore, the relative isolation of the crew members is almost the same in both types of aircraft. As there have been relatively few fighter pilots (5) who have had cases of anoxia reported, these have been simply included in the totals.

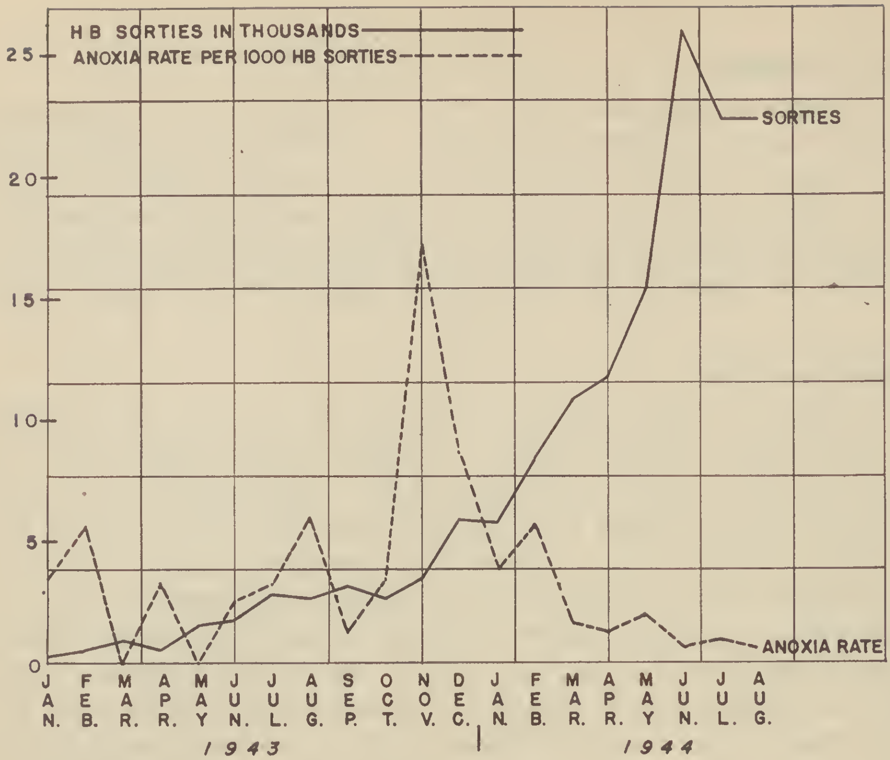
5. Sources of Error.

That there is a serious error in this study as far as total number of cases is concerned, can be seen in the fact that for certain periods many cases of anoxia have been reported in the "Care of Flier Report" for which detailed reports have not been forwarded. Furthermore, cases of anoxia have been reported in detail which do not appear on the "Care of Flier Report." There are, therefore, inaccuracies and it has been necessary to assume that the cases studied actually represent a true sample of all the cases that occurred. That all cases occurring are not reported is further evidenced by a study recently made by Captain Ward S. Fowler, MC, Aviation Physiologist, at 2d Combat Crew Replacement Group ("Survey of Anoxia Experience in Heavy Bomber Crew Members"). This study showed that approximately 69% of aircrew personnel finishing their tours had at one time or other experienced anoxia of varying degree, while on combat, and approximately 43% two or more times. The obvious conclusion is that the present study covers only moderate, severe and fatal anoxia where unconsciousness was a main feature for the non-fatal cases. The mild cases in which there is no loss of consciousness have evidently not been reported to any large degree.

II. GENERAL TREND FOR FATAL AND NON-FATAL CASES OF ANOXIA.

1. Trend for Fatal and Non-Fatal Cases.

The first reported case of anoxia in an operational flight in the Eighth Air Force occurred in January 1943. During that month and the first six months of 1943, the number of sorties per mission was small, missions were infrequent and cases of anoxia relatively few. (A heavy bomber sortie represents, on the average, 10 man-sorties.) No non-fatal cases are reported for September or October 1943 though the fact that some occurred and were not reported is evidenced from the appearance of cases in the "Care of Flier Report" for that period. In November 1943, operations against "Festung Europa" were on in earnest and there was a marked rise in the total rate, to 18.1 per thousand heavy bomber sorties. (See accompanying graph.)




After that period there has been a fairly steady and progressive drop in the rate, which for July and for August 1944 was less than one per thousand heavy bomber sorties.

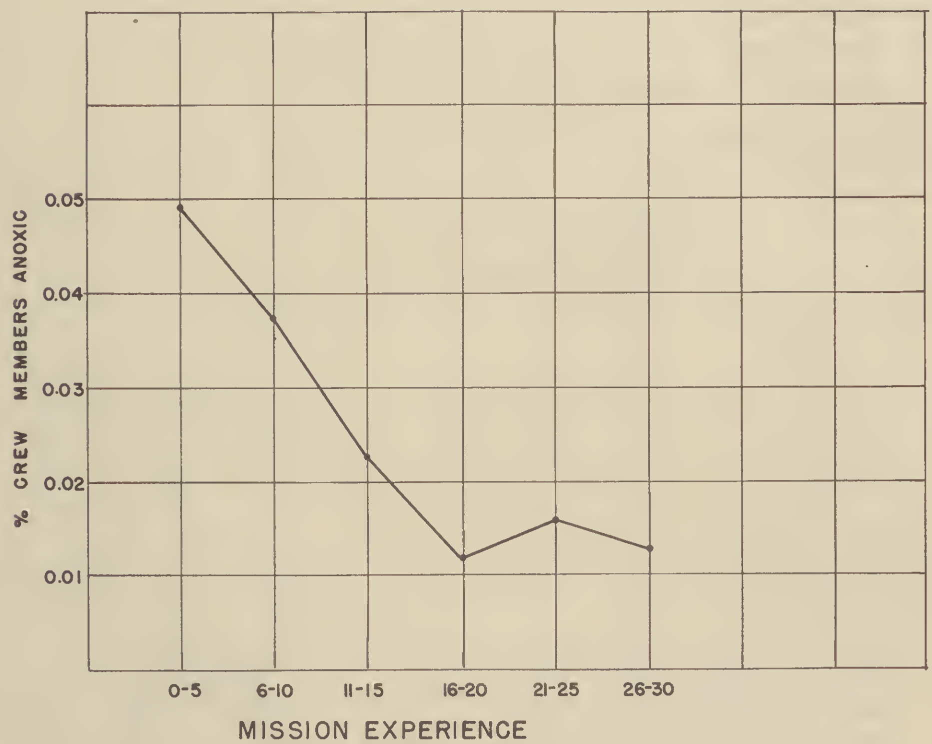
2. Factors Influencing Trend.

There is no one specific factor to which this satisfactory drop in rate can be ascribed. In general, two main categories have been involved. First, improvement in the oxygen equipment and secondly, improvement in the indoctrination received by the air-crews. In the first category, of paramount importance is the changeover from the constant flow oxygen system to the demand system with the decreased danger of freezing of the mask and the increased reliability of proper oxygenation. Equally important from this standpoint has been the closure of the waist windows. Less striking, but probably just as significent improvements consisted of the substitution of the D-2 bottle as a walk-around instead of the inadequate A-4 bottle, the development of a lock for the demand system quick disconnect and the modification of the A-14 mask to decrease its freezing tendency. In the second category is the improvement in training and indoctrination in the use of oxygen and oxygen equipment. This indoctrination has been given by the Personal Equipment Officers of the Groups and Squadrons, by the instructors at the Combat Crew Replacement Centers and in the United States, in the Altitude Training Units. All these factors have played a definite role in bringing about this decrease in rate though the extent and importance of each cannot be evaluated.

## III. RELATION OF ANOXIA TO COMBAT EXPERIENCE.

A cursory examination of the groupings into which those who have suffered from anoxia fall, with regard to their mission experience, indicates that a very great proportion have their trouble in the first five missions. The following data and graph show how important this effect is regardless of the effect of attrition rate for air-crews. The data are given for the period 1 January 1944 through 20 August 1944.

| Mission Experience | Percent of Aircrew Members Anoxic |
|---|---|
| 0-5 | .044 |
| 6-10 | .037 |
| 11-15 | .023 |
| 16-20 | .012 |
| 21-25 | .017 |
| 26-30 | .013 |
| 31-35 | .000 |




If the occurrence of anoxia in combat personnel were an event dictated entirely by chance, with an equal probability of occurrence on any missions, the curve in the above graph would be a straight line parallel to the X-axis and the percentage of aircrew personnel anoxic in a given mission group would be more or less constant. That a higher percentage of aircrew get anoxic in their early missions is obvious from the figures and the graph. Combat experience, therefore, apparently teaches individuals the need for constant care and attention to their oxygen equipment to prevent avoidable accidents. For example,

separation of a quick disconnect while firing a gun can hardly be considered a personnel failure, but it is less likely to occur if the individual concerned has learned from experience that accidental separation is possible. That increase in combat experience is followed by a decrease in anoxia rate is indicative of the need for further emphasis on oxygen problems during the training period.

## IV. CAUSES OF ANOXIA INCIDENTS

1. In most of the cases it has been possible to determine the cause of the accident, though in some it has been necessary to interpret the reports liberally in view of the inadequacy of the reports themselves. Wherever possible, the findings have been checked, but sometimes to no avail.

a. Non-Fatal Cases. The causes of non-fatal cases follow. (Details concerning the causes are given later in this report).

| Cause | Percent | |
|---|---|---|
| Quick Disconnect Failure | 23.4 | |
| Personnel Failure | 13.3 | |
| Regulator Failure | 8.6 | |
| Freezing of A-14 Mask | 7.8 | |
| Mask Difficulty, A-14 | 4.7 | |
| *Freezing of A-8B Mask | 3.5 | |
| Battle Damage | 3.1 | |
| *Freezing of A-10 Mask | 3.1 | |
| *Freezing of A-10A and A-10R Mask | 3.1 | |
| *Mask Difficulty, A-10 | 2.7 | |
| *Mask Difficulty, A-10A and A-10R | 2.3 | |
| Regulator Elbow | 2.3 | |
| Filler Valve | 2.3 | |
| *A-4 Bottle | 2.0 | |
| Mask Difficulty, A-14 (8th AF Mod.) | 2.0 | |
| *A-2 Bottle | 1.6 | |
| Line Leaks | 1.6 | |
| Freezing A-14 (8th AF Mod.) | 1.6 | |
| Kinking of Mask Hose | 0.8 | |
| Quick Disconnect Gasket | 0.4 | |
| Miscellaneous | 3.2 | |
| Mask accidentally knocked off | | (1.2) |
| Mask given to another man. | | (0.4) |
| Mask off to vomit. | | (0.4) |
| Mask to regulator tubing pulled off to regulator. | | (0.4) |
| Valve to top turret turned off. | | (0.4) |
| Exhausted ball turret supply. | | (0.4) |
| Undetermined | 6.6 | |

* That the number of cases attributed to these causes is not greater is most likely due to the fact that these items have been used only for very limited periods or in very limited numbers.

b. Fatal Cases. The causes for fatal cases are as follows:

| Cause | Percent |
|---|---|
| Quick Disconnect Failure | 25.6 |
| Freezing of A-14 Mask | 21.2 |
| Freezing of A-8B Mask | 10.6 |
| Personnel Failure | 7.5 |
| Battle Damage | 5.3 |
| Lost Walk-Around Bottle in Bombay | 4.3 |
| Freezing of A-10 Mask | 2.1 |
| Freezing of A-10R or A-10A | 2.1 |
| A-2 Bottle Failure | 2.1 |
| Undetermined | 19.1 |

Here, as in the non-fatal cases, a large proportion of accidents have been caused by the quick disconnect, but freezing of the A-14 mask is a close second. Of the cases of freezing of the A-14, most have frozen in the inlet ducts but some also at the outlet ports. Freezing of the A-8B mask while third in order of importance in the overall figures has not been responsible for a death since November 1943, however, it must be pointed out that this mask was used infrequently after this date.

c. Fatal and Non-Fatal Cases. The overall percentages for the various cases follow for both fatal and non-fatal cases.

| Cause | Percent |
|---|---|
| Quick Disconnect | 23.8 |
| Personnel Failure | 12.4 |
| Freezing A-14 Mask | 9.9 |
| Regulator Failure | 7.3 |
| Freezing A-8B Mask | 4.6 |
| Mask Difficulty, A-14 | 4.0 |
| Battle Damage | 3.5 |
| Miscellaneous | 3.3 |
| Freezing A-10 Mask | 3.0 |
| Freezing A-10R and A-10A | 3.0 |
| Mask Difficulty, A-10 | 2.3 |
| Mask Difficulty, A-10A and A-10R | 2.0 |
| Regulator Elbow | 2.0 |
| Filler Valve | 2.0 |
| A-4 Bottle | 1.6 |
| A-2 Bottle | 1.6 |
| Mask Difficulty, A-14 (8th AF Mod.) | 1.6 |
| Line Leaks | 1.3 |
| Freezing A-14 (8th AF Mod.) | 1.3 |
| Kinking of Mask Hose | 0.7 |
| Quick Disconnect Gasket | 0.3 |
| Undetermined | 8.6 |

d. Discussion of the Causes of Failure. The different causes of the cases of anoxia reported above will be discussed briefly to clarify the nature of the failures:-

(1) Quick Disconnect. There have already been several reports in which attention has been directed to the unsatisfactory nature of the quick disconnect (Eighth Air Force CME Project Reports as follows: Project No. 153, 14 March 1944; Projects Nos. 153, 163, 181 and 187, 29 June 1944). At this point, therefore, it will suffice to say that the difficulty experienced has been constant and can be only partially taken care of by such a measure as the adjustment of the prongs on the male portion of the quick disconnect. Too often, there is great variation in the size of the female portions which can be corrected only by replacement of the unit. To a certain degree of late the situation has been temporarily remedied by the wider use of the Hight Lock (ASC Modification M-45), but there is the objection that this item requires deliberate use by the crew member equipped with it and a fully automatic locking device would be far more satisfactory. There has been, however, no reported cases of failure of this lock. At least three cases have been reported where the lock was available but not used. This emphasizes again the need for constant indoctrination.

(2) Personnel Failure. A part of these failures have been due to lack of adequate indoctrination and training -- crews trained in the use of the constant flow oxygen system have been put in a ship equipped with the demand system and on at least one occasion a crew familiar only with the demand system has been put in a ship equipped with the constant flow system with unfortunate results. This type of accident has, of course, disappeared since only the demand system is at present used in operational aircraft. It is likely, however, that any similar radical change in equipment, not preceded by proper indoctrination, would result in the same type of confusion. There has also been an occasional case of an observer, not at all indoctrinated in high altitude conditions, being allowed to fly at high altitudes or on an operational mission. Other types of failure have been the result of gross ignorance, e.g., trying to plug a demand mask connection into a constant flow outlet or trying to walk the length of an aircraft without a walk-around bottle. Constant emphasis on the use of various items of personal equipment must be made by the Personal Equipment Officers and the Flight Surgeons in order to reduce the incidence of personnel failures for these failures are the ones which are the most amenable to correction. It is felt that some improvement is being made, but the constant variation in amount of training of crews in high altitude flying and the relatively small number of anoxia cases due to personnel failure make a correct evaluation of a trend impossible at present.

(3) Freezing of A-14 Mask. The A-14 Mask was at first estimated to be entirely satisfactory for use in the Eighth Air Force on the basis of limited service tests carried out in the Eighth Fighter Command. Unfortunately, as was found subsequently, the A-14 Mask had a definite tendency to freeze in the inlet ducts and some modification was essential. The use of a heater was precluded by the wide variety of electrically heated suits which would have required modification. A simple patch cemented in to raise the level of the inlets was found adequate and considerably decreased the number of incidents of anoxia from freezing of the A-14 Mask.

Since introduction of the modified mask in the Eighth Air Force in February 1944, there have been no cases of death due to freezing of the modified masks and only a very few non-fatal cases. In the same period, there have been deaths and non-fatal cases due to freezing of the unmodified mask. This fact emphasizes the difficulties encountered in any attempt to modify equipment at combat installations, particularly during a period when the number of flying personnel is increasing rapidly.

(4) Regulator Failure. While a relatively large number of cases of regulator failure have been reported, quite frequently the reports are not specific enough as to the exact cause. One main cause was the rupture of the diaphragm in the Aro type regulator due to misuse. This difficulty is being surmounted by the reinforcing of the diaphragm and the introduction of a safety blow-off valve in the second stage reduction. Recently attention has been called to sticking of the regulator diaphragm in a depressed position so that all the oxygen in a system is lost, resulting in anoxia. There have also been a few cases in which the regulators have failed and there has been some indirect evidence that there was blockage by ice in the line or the regulator itself. These troubles with icing can only be prevented by the use of driers on the charging carts.

(5) Freezing of the A-8B Mask. This was one of the first difficulties experienced with the oxygen system in operational aircraft. The freezing took place in the sponge rubber discs, the bag and in the bakelite connecting portion from where it was impossible to remove the ice. The situation was completely corrected by making sole use of demand oxygen equipment in the operational aircraft of the Eighth Air Force. Since November 1943, there have been no deaths due to freezing of the A-8B mask and only a very few non-fatal cases. However, this mask was used infrequently since this date.

(6) Mask Difficulty. This refers to suspension failures, loss or breakage of suspension hooks, exhaust valve sticking, etc., in which there was no personnel failure but in which there was some evidence of equipment difficulty.

(7) Battle Damage. This classification comprises damage by enemy action to any part of the oxygen equipment, whether cylinders, lines, regulator, tubing or mask.

(8) Regulator Elbow. While accidental loosening of the regulator elbow has been responsible for but a small percentage of cases of anoxia, it has proven to be a constant source of trouble, requiring constant attention to avoid serious accidents. An elbow lock has been developed by the Aero-Medical Laboratory and was field service tested in the Eighth Air Force. These tests were favorable.

(9) Filler Valves. One of the main causes of "mechanical" abortions and of anoxia in operational aircraft has been the failure of the filler valves used to recharge the walk-around bottles. A filler valve which neither jams nor freezes open has, as far as is known, not yet been put into mass production though an experimental one which may prove satisfactory has been developed.

(10) A-4 Walk Around Bottle. The inadequate capacity of the Type A-4 Walk Around Bottle has been previously reported and the type D-2 cylinder has been substituted where possible. That some cases of anoxia are still reported occasionally from the A-4 bottle arises from the fact that there has been, until recently, a shortage of the D-2 cylinders. It is expected that the anoxia incidents due to the A-4 bottle, may soon disappear. A new type of walk-around is being developed. This assembly will be service tested as soon as sufficient units become available.

(11) A-2 Bottle. The few cases of anoxia caused by the A-2 walk around bottle have primarily arisen from the difficulty that exists in shifting from the demand to the constant flow system. Another source of trouble has been the difficulty in opening the main valve of the A-2 bottle under cold conditions.

(12) Quick Disconnect Gasket. The gasket on the male portion of the quick disconnect had a deplorable tendency to slip off and become lost, making it impossible to obtain a good seal between the mask tubing and the mask regulator tubing. This condition has been taken care of by the introduction into general use of the new type gasket with an extra lip.

(13) Kinking of Mask Hose. While anoxia has infrequently resulted from kinking of the mask hose, there have been many complaints about the kinking. A wire reinforced tubing while kink-proof is too heavy to be satisfactory. The Aero-Medical Laboratory, following the lead of the R.A.F., has developed kink-proof rubber tubing which may prove satisfactory. Service tests are to be conducted when the tubings become available.

V. RELATION OF POSITION IN AIRCRAFT TO ANOXIA INCIDENTS:

1. While the possibility of anoxia occurring because of an equipment failure may be the same for all positions in heavy bombardment aircraft, the probability of serious anoxia may be expected to be greater in the more isolated positions. Since this study almost certainly comprises only serious anoxia and definitely does not give a true estimate of equipment failures, it must be borne in mind that the isolation of the crew members is a most important factor. The following data give the percent of cases of anoxia occurring at various positions in heavy bomber aircraft, both B-17's and B-24's, for the period August 1942 through August 1944.

a. Non-Fatal Cases:

| Position | Percent |
|---|---|
| Pilot | 5.8 |
| Co-Pilot | 2.1 |
| Navigator | 10.3 |
| Bombardier | 5.0 |
| Top Turret Gunner | 7.8 |
| Radio Operator | 13.6 |
| Waist Gunner | 17.3 (8.67 x 2) |
| Ball Turret Gunners | 23.6 |
| Tail Gunner | 14.5 |

(1) Ball Turret Gunners. (23.6%) From the above data it can be seen that the ball turret is the position in which non-fatal anoxia is most frequently encountered. One factor has been the inadequate oxygen supply of ball turret gunners (this was true until the arrival of newer aircraft with the oxygen supply running off one of the main systems) and the isolation of the gunners. While they are in the visual range of radio operators and waist gunners, the spherical turret itself offers obstruction to vision. This is borne out by the fact that the anoxic condition was discovered by lack of response to intercom check and by other crew members who were attracted by the position of the turret or of the gunner himself. In addition, some gunners themselves discovered they were in trouble and tried to get out of the turret only to become unconscious when they had gotten part way out. They were then found by the other crew members. This difficulty in getting out of the ball turret arises from the cramped quarters which do not allow a walk around bottle to be carried along. The A-2 bottle could fit into the turret but requires changing masks which is impractical and furthermore dangerous, the D-2 oxygen cylinder is too bulky and the A-4 bottle inadequate. Several solutions have been suggested:

(a) Use of the A-2 bottle with a high pressure demand regulator.

This, however, is not favored because of the danger attendant in the use of high pressure cylinders.

(b) An extensible hose which would allow the ball turret gunner to stay on the turret supply while getting out until he could plug into another regulator.

(c) A demand walk-around bottle smaller than the D-2 but more adequate than the A-4 which could be carried in the turret.

(2) Tail Gunners. (14.5%) In this the second largest group, the geographical isolation is greater than for the ball turret gunners, particularly in B-17 aircraft where the structure of the tail wheel-well obstructs direct vision completely. Amongst these, most were found to be in trouble by the lack of response to the intercom check. Some were found visually, and others either helped themselves or recovered on descent.

(3) Radio Operators. (13.6%) The radio operators are in a similarly isolated position as the tail gunners for they are not in direct visual contact with the other crew members. Here too, most were discovered by intercom check, others were seen to be in trouble and a few helped themselves. No details are available about the remainder.

(4) Waist Gunners. (17.3%) In total numerical strength, these are second. Only a few were found by intercom check. Most were seen to be in trouble and a few helped themselves.

(5) Navigators. (10.3%) Most of these as might be expected, were discovered by other crew members, usually the bombardiers; only few were discovered to be in trouble by intercom check.

(6) Top Turret Gunners. (7.8%) The top turret gunners are in fairly close visual contact with other crew members but in case of trouble, they may be forgotten and their difficulties discovered by a later intercom check.

(7) Other Positions. The pilot, co-pilot and bombardier are each located close to another individual so that their difficulties are apt to be much less than for others. Usually, intercom check is not necessary and a visual check is sufficient.

b. Fatal Cases.

| Position | Percent |
| --- | --- |
| Pilot | 0 |
| Co-Pilot | 0 |
| Navigator | 6.4 |
| Bombardier | 4.3 |

| | |
|---|---|
| Top Turret Gunner | 12.8 |
| Radio Operator | 17.0 |
| Waist Gunner | 23.4 (11.7 x 2) |
| Ball Turret Gunner | 8.5 |
| Tail Gunner | 27.6 |

(1) Tail Gunners. (27.6%) The main difference between the fatal and non-fatal cases lies in the fact that more tail gunners suffered from fatal anoxia than individuals in other positions, while more ball turret gunners suffered from non-fatal anoxia. The explanation of this apparent discrepancy lies in the fact that while, actually, ball turret gunners are more apt to become anoxic because of equipment difficulties, they are also more likely to be rescued earlier than are tail gunners since the ball turret gunners can be checked both by intercom and visually. Of the tail gunners, most were found to be in trouble through the intercom, some, however, were seen. The average time between the last period of normal function and the discovery of the difficulty for more than half of the anoxic tail gunners was seven minutes.

(2) Radio Operators. (17.0%) Most of the radio operators were found to be in trouble through the intercom and a few were discovered by other crew members. The average time between last period of normal function and discovery of anoxia was 13 minutes for the radio operators.

(3) Waist Gunners. (23.4%) Of these, only a few were found to be in difficulty by the intercom and most were found by other crew members. The average time for a few of these individuals between last known normal function and the discovery of anoxia is 30 minutes.

(4) Top Turret Gunners. (12.8%) Of these, a few were found to be in trouble by intercom check and most visually. For a few the average time between last normal function and discovery of anoxia was 12 minutes.

(5) Ball Turret Gunners and Others. For these and other crewmen (navigators and bombardiers) insufficient data are available to make any analysis worthwhile.

c. Overall Position Distribution for Fatal and Non-Fatal Cases.

| Position | Percent |
|---|---|
| Pilot | 4.8 |
| Co-Pilot | 1.7 |
| Navigator | 9.7 |

| | |
|---|---|
| Bombardier | 5.2 |
| Top Turret Gunner | 8.6 |
| Radio Operator | 14.2 |
| Waist Gunner | 18.3 (9.17 x 2) |
| Ball Turret Gunner | 20.8 |
| Tail Gunner | 16.6 |

N.B. The figures in parenthesis for the waist gunners simply indicate the estimated figures for each waist gunner.

## VI. DISCUSSION OF DATA.

While the importance of position, equipment failure, and combat experience have been discussed alone, it is desirable to indicate the role that may be played by other factors and particularly how individuals are discovered to be in trouble.

1. Detection of Anoxia by other Crew Members. It is the universal habit in heavy bombardment aircraft to have periodic intercom checks of all individuals in the aircraft to determine whether they are in any difficulty. It is obvious that in view of the hazard which increases with altitude, the checks should be more frequent the higher the altitude and should certainly be made no less often than every three minutes at altitudes above 25,000 feet. The outcome of these checks is satisfactory as a large proportion of crew members have been discovered as a result of this. Unfortunately, this use of the intercom interferes greatly with the tactical use of the intercom in reporting enemy aircraft, flak, etc. Visual checks are too unreliable to be depended on and furthermore, require that attention be distracted from the primary duty of the individual. Another means of detection has been suggested, which makes use of a special instrument warning panel. The first mention of a system depending on a blinking-light panel came from the 3d Bombardment Division. It was suggested that a central panel be located near the bombardier with one light for each crew position or regulator. The lights would blink with every breath taken as a circuit would be interrupted or made by the rise and fall of the regulator diaphragm. Another suggestion was made by the 3d Bombardment Division at a later date. This modified system made use of the blinker flow indicator assembly as the make and break of the circuit. This proved very successful in freeing the intercom and permitting easy and accurate check. It must be pointed out, however, that this type of indicator will only indicate whether or not the diaphragm is rising and falling and is not an anoxia indicator. Occasional checks by the intercom would still be necessary. It would be possible, however, to determine if a crew member were at his position and if he were not, an intercom check could be made and some other crew member asked to investigate. In summary, then, anoxia or difficulty with oxygen equipment can be detected in the following way:-

a. By intercom check.

b. Visually.

c. By warning panels.

2. Resuscitation of Anoxic Crew Members. The procedure employed in the resuscitation of anoxic crew members depends on the degree of anoxia encountered.

a. Mild Anoxia, without Unconsciousness. In these cases, a quick check of the difficulty and correction (e.g., disconnected quick disconnect) and then turning of the automix to the "off" position is usually sufficient. On several occasions, however, when a mask has been dislodged and is refitted, the anoxic individual often becomes maniacal and several rescuers have become anoxic as the result of the misdirected activity of the individuals they were trying to assist. The net result is often two victims instead of one. In one instance, a bombardier became anoxic near the target; an attempt was made to revive him but he became so violent that it was necessary to let him go completely unconscious so that the bombs could be dropped by another crew member.

b. Anoxia with Unconsciousness but still breathing. Under these circumstances, it is generally sufficient to turn the automix off and occasionally give a small steady flow with the emergency valve slightly on. Again, here, maniacal reactions may be encountered.

c. Unconsciousness with no Definite Evidence of Breathing. Here, of course, the obvious course is to give oxygen and artificial respiration. There is some admittedly questionable evidence that there were signs of life in some of the individuals (flickering of eyelids, palpable pulse, etc.) and that very shortly after oxygen was administered, all signs of life disappeared. To all intents and purposes, the man died shortly after the administration of oxygen.

While the last condition (i.e., death ensuing after oxygen administration) described above may be an artefact, it still again raises the question of whether the administration of $CO_2$ - $O_2$ mixtures for resuscitation of anoxic individuals may not be more desirable than $O_2$ alone.

3. Evaluation of Trends. Little will be said here except to emphasize again the probability that the present study represents only moderately severe and severe anoxia. Relatively few cases have been reported from B-24 aircraft, and no attempt has been made to differentiate between the two because of the difficulty of obtaining accurate data on the relative numbers used on various missions. Mission frequency, furthermore, has not been considered because of the impossibility of determining whether the same crews are always sent out on successive missions in the various Operational Groups in the Eighth Air Force.

VII. SUMMARY AND CONCLUSIONS.

1. These figures represent only moderately severe and severe anoxia. Very few of the mild cases of anoxia have been reported.

2. This report applies primarily to heavy bombers as only a few cases of anoxia in fighter pilots have been reported.

3. The reports of anoxia have proven to be in many instances inadequate both with regard to technical details and medical details.

4. The peak for anoxia cases came in November 1943 with an overall rate of 18.1 cases per 1,000 heavy bomber aircraft sorties.

5. Combat experience has a definite effect in decreasing the incidence of anoxia, indicating the need for more careful training.

6. The training and indoctrination of aircrews has improved but the standard could be raised advantageously, especially with regard to experiencing anoxia in the altitude training units in the United States.

7. The most important causes of non-fatal anoxia are in order of importance:

a. Quick disconnect failure.

b. Personnel failure.

c. Regulator failure.

d. Freezing of the A-14 mask.

8. The most important causes of fatal anoxia are, in order of importance (at present):

a. Quick disconnect failure.

b. Freezing of the A-14 mask.

c. Personnel failure.

9. Attempts are being made to remedy the mechanical causes of anoxia by various modifications of existing equipment and the design of new equipment.

10. The crew positions in heavy bomber aircraft at which crew members are most likely to experience non-fatal anoxia are: (In decreasing order of importance.)

a. Ball turret gunners.

b. Tail gunners.

c. Radio operators.

d. Navigators.

e. Waist gunners.

f. Top turret gunners.

The named stations apply to equivalent positions in B-17's and B-24's.

11. The positions at which fatal anoxia is most likely to be encountered are:

a. Tail gunners.

b. Radio operators.

c. Top turret gunners,

d. Waist gunners.

e. Ball turret gunners.

12. A large number of anoxic cases are discovered by the lack of response to an intercom check; the rest mainly by visual check from crew members nearby.

VIII. RECOMMENDATIONS.

1. That anoxia reports be rendered in detail on cases of moderate, severe and fatal anoxia only, after investigation by the flight surgeon and personal equipment officer concerned, who will be jointly responsible.

2. That cases of mild anoxia, not resulting in loss of consciousness be reported only by number and cause in the "Care of Flier Report."

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* * *

## BREATH HOLDING DEMONSTRATIONS AS A TEACHING AID IN ALTITUDE TRAINING

A real need exists for methods to demonstrate objectively to Aviation Trainees physiological effects on the body at relatively low altitudes and the necessity for using an oxygen mask between 10,000 and 15,000 feet. Engel, Webb, and Ferris, 1944, reported a direct proportional relationship between the maximum time of breath holding and the atmospheric pressure (Bumed News Letter Aviation Supplement, 18 February 1944). A consistent decrease in ability to hold the breath occurred at altitudes as low as 7,000 feet. Consequently the authors suggested that simple breath holding experiments might be used as an objective method for demonstrating effects on the function of the body at low altitudes.

At the 29th Altitude Training Unit, San Antonio Aviation Cadet Center, breath holding demonstrations have been tested for practicability as a teaching aid in altitude training during one hundred and thirteen (113) simulated flights in the low pressure chamber. On each flight a volunteer Aviation Trainee was instructed to inspire deeply and hold his breath as long as possible at ground level, at 10,000 feet and again at 18,000 feet without the use of an oxygen mask. The crew chief recorded the periods of time with a navigation stopwatch. The results indicated a decrease in breath holding ability clearly demonstrable at 10,000 feet in seventy-nine percent (79%) of the

experiments, and a further decrease at 18,000 feet, in comparison with that at 10,000 feet, in ninety-six percent (96%). A greater degree of success might be expected with additional care in requiring the subject to hold his breath maximally at ground level and with the use of several trials. Average breath holding times are presented in the following table. These data have been shown to be statistically significant.

AVERAGE BREATH HOLDING TIMES IN 113 DEMONSTRATIONS

| Ground Level | 10,000 Feet | 18,000 Feet |
|---|---|---|
| 59.1 Secs. | 45.7 Secs. | 36.9 Secs. |

Breath holding demonstrations have been found to constitute a simple, dependable, and effective method for showing a decrease in ability of the body to perform normally at altitudes as low as 10,000 feet. This method takes less time than the use of either the Millikan Oximeter or the cardiotachometer, which require considerable adjustment and lengthy explanations. It is more dependable than such electrical gadgets which get out of order frequently with repeated use and with operation by different individuals. The demonstrations attract attention and create interest since the Aviation Trainees in the chamber may time the subject themselves. The breath holding demonstrations are now in routine use as a teaching aid in Altitude Training by the 29th Altitude Training Unit, San Antonio Aviation Cadet Center.

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* * *

## NEURO-CIRCULATORY COLLAPSE IN ALTITUDE CHAMBERS

### Electroencephalographic Studies

1. Purpose: To study the electroencephalographic patterns and related factors in individuals who have shown neuro-circulatory collapse in altitude chambers.

2. Definitions:

a. Neuro-Circulatory Collapse (NCC): The term neuro-circulatory collapse in this study is used to describe the syncopal reactions which occur during the ten minute anoxia period at a simulated altitude of 18,000 feet in altitude chambers and will be referred to in this report as NCC. The NCC reaction is characterized by greenish pallor, sweating, bradycardia, apathetic facies, loss of interest in

surroundings, terminal fall in blood pressure, and ultimate flaccid unconsciousness. In rare cases, nausea or vomiting may precede or follow the unconsciousness and there may be convulsive movements.

b. Twice NCC: All individuals who show the NCC reaction on their first chamber flight are given an identical recheck flight at a later time and those few (5% to 15%) who again suffer this reaction are termed "twice-NCC."

c. Controls: Individuals who showed no evidence of the NCC reaction during their chamber flight are taken as controls in this study.

3. Methods:

a. Subjects for these electroencephalographic studies were chosen at random from the 2.0% of cadets suffering NCC reactions at this Altitude Training Unit in the course of standard altitude chamber flights. These flights involve a preliminary ear check ascent to 5,000 feet and descent to ground level, followed by an ascent to 18,000 feet at a rate of 3,000 feet per minute and interrupted by a 5 minute stay at a simulated altitude of 10,000 feet. At 18,000 feet there is a 10 minute period of anoxia following which the use of oxygen is started for the first time. The NCC reactions occurred during the 10 minute anoxia period at 18,000 feet. Individuals who developed NCC were given oxygen and removed via the chamber lock to ground level where blood pressure and other studies were carried out. After recovery was complete, (accelerated by breathing oxygen at rest in a recumbent position), those to be further studied were taken to the EEG Room. Occasionally individuals were not studied electroencephalographically until the following morning; in every case at least one hour and usually several hours elapsed between apparent complete clinical recovery and the electroencephalographic recording.

b. The Grass 4 channel EEG was used, with solder electrodes held in place with collodion and applied to the right, midline, and left frontal, parietal, and occipital areas. Ear electrodes served as grounds for the monopolar recordings; bipolar recordings were also used. After 12-15 minutes of resting record, further records were taken during three minutes of maximal hyperventilation and for 3 to 5 minutes thereafter. At the conclusion of the record blood was drawn from the antecubital vein, and blood sugars determined by the Folin-Wu method (using the Leitz colorimeter) in the chemistry laboratory of the Hospital.

c. In the analysis of the records, the Davis (1) scale of rating has been employed:

"Rating 1 is given to any normal type of pattern which is stable in its fluctuations of frequency and voltage within fairly narrow limits and without any sharp transitions."

"Rating 2 includes normal records which are slightly less stable or regular than those rated 1."

"Rating 3 includes normal records in which some features may be exaggerated but cannot be regarded as abnormal."

"Rating 4 is given to any record which is dysrhythmic and suspicious and has recognized abnormalities clearly indicated, but no feature typical or outstanding enough to warrant definite diagnosis."

"Rating 5 is given to any record which reveals recognized abnormal dysrhythmias such as those found in epilepsy."

d. In order to conform with War Department Technical Bulletin (TB MED 74, 27 July 1944, Electroencephalograph: Operative Technique and Interpretation), the Davis rating scale is equated with the Gibbs' Classification in Table 1 and in Legend to Figure 1.

4. Observations:

a. The electroencephalographic findings in 54 cases of NCC and in a small series of 20 controls are tabulated below. Of these 54 cases of NCC, 33 showed the NCC reaction once only and subsequently completed their recheck flight successfully; 21 were twice-NCC with an interval of one week or more between reactions.

| EEG RATING | CONTROLS | ONCE-NCC | TWICE-NCC | ALL NCC's |
|---|---|---|---|---|
| 1 | 1 | 2 | 1 | 3 |
| 2 | 8 | 17 | 7 | 24 |
| 3 | 8 | 7 | 8 | 15 |
| 4 | 3 | 6 | 5 | 11 |
| 5 | 0 | 1 | 0 | 1 |
| TOTALS | 20 | 33 | 21 | 54 |

b. Considering the electroencephalographic ratings of 4 and 5 abnormal, it is seen in the above table that there was a slightly greater percentage of abnormal records among the NCC cases than among the controls (22% compared with 15%). This difference is of very dubious significance, however, in view of the small numbers of cases involved.

c. There was no significant difference between the group which had their EEG recordings on the same day as their NCC and those having them on later days. Among the abnormal records, later recordings confirmed the earlier ones.

d. The incidence of abnormal records among the twice-NCC's was 23.8% and among those who were once-NCC 21.2%. This is not a significant difference.

e. There were no significant relationships between the level of blood sugar, the time at altitude before collapse, and occurrence of nausea, vomiting, or convulsive movements, and the type of EEG found.

f. Relation to convulsive states:

(1) Only two once-NCC's and two twice-NCC's showed convulsive movements (tonic jerkings of the body and extremities without tongue biting or incontinence) during their period of unconsciousness; these ceased promptly after administration of oxygen. One of each pair had abnormal records, and in each case a second confirmatory

recording was made some days later to eliminate a possible effect of anoxia outlasting clinical recovery.

(2) In no case could any history of epilepsy or other nervous or mental disease be obtained from the cadets. This negative history is of notoriously poor value because of the effect such admissions might have on the cadets' future status. One single-NCC case had the only diagnostically abnormal EEG record (rating 5) which was repeated and confirmed on a later occasion before the second flight which he successfully completed. Very careful questioning of this individual failed to reveal any pertinent history.

(3) Of two cadets who are known to have received altitude chamber flights and to have later been diagnosed as epileptics, one of a grand mal type, neither suffered NCC in the altitude chambers. Follow-up of 1,000 cases of NCC has failed to reveal any overt epileptic in the group.

5. Discussion:

a. From this study, there is no evidence that NCC cases on simulated flights at 18,000 feet without additional oxygen have any higher incidence of "abnormal" electroencephalograms than do other individuals who do not show this syncope. Furthermore, those who have such reactions twice have no more abnormal records than those with one such NCC reaction.

b. It is well known that stress (such as pH change, acapnia of hyperventilation, oxygen deprivation, and hypoglycemia) can induce convulsions more often in predisposed individuals than in normals (for a given amount of stress). However, the reactors in this group, subjected to mild oxygen deprivation, have no such predisposition as indicated by electroencephalographic study.

c. Hypoglycemia is not a factor: Earlier studies at this Altitude Training Unit compared the blood sugar levels of 28 individuals immediately after collapse and while still in the altitude chamber with 50 chamber-mate controls. (Reference letter, this Altitude Training Unit, sub: "Special Investigations," 3 November 1943, file no 221.01). The blood sugar levels in the present study, taken from individuals at the end of the EEG record, and, therefore, an hour to a day or so after removal from the altitude chamber show similar non-significant findings:

| | 1943 Studies | | 1944 Studies | |
|---|---|---|---|---|
| | Controls | NCC's | Once-NCC | Twice-NCC |
| Number of Cases: | 50 | 28 | 22 | 13 |
| Range: | 74-143 | 74-133 | 83-161 | 83-145 |
| Arithmetic mean: | 92 | 93 | 113 | 107 |
| Standard deviations: | 12.3 | 13.2 | 21.8 | 16.1 |

d. If the stress of anoxia alone were to account for the neuro-circulatory collapse, then there should be a greater incidence of collapse in the later minutes of the flight: actually, most of the collapse cases occurred within the first 5 minutes:

Time at 18,000 feet before unconsciousness

| Time (min) | Once-NCC | Twice-NCC First Flight | Twice-NCC Second Flight | Twice-NCC Both Flights | All NCC's |
|---|---|---|---|---|---|
| 1 | 2 | 1 | 1 | 2 | 4 |
| 2 | 1 | 1 | 4 | 5 | 6 |
| 3 | 4 | 4 | 2 | 6 | 10 |
| 4 | 5 | 8 | 6 | 14 | 19 |
| 5 | 11 | 0 | 1 | 1 | 12 |
| 6 | 5 | 2 | 4 | 6 | 11 |
| 7 | 1 | 1 | 0 | 1 | 2 |
| 8 | 2 | 1 | 1 | 2 | 4 |
| 9 | 1 | 1 | 1 | 2 | 3 |
| 10 | 0 | 0 | 1 | 1 | 1 |

These results accord well with those found in a larger series (1,000 cases) to be reported later from this Unit.

e. If, as seems likely, the syncopal reactions are not predicated on an epileptic basis, the most obvious underlying mechanism would appear to be a psychosomatic one, somewhat allied to the fainting of individuals on veni-puncture or on sight of blood. The following may be of interest in this regard: McFarland and Barach (2) studied the response of psycho-neurotics to low oxygen tensions and found 70% collapsed at 18,000 feet compared to only 14% of controls. McFarland has concluded (2, p.75), "It is quite possible that individuals who are under temporary or chronic emotional stress are apt to acclimatize poorly to a reduction in oxygen pressure since the nervous mechanisms involved in adaptation to oxygen lack are reported to be somewhat similar to the ones involved in emotional experiences (sympathetic nervous system)." While the NCC reaction in our opinion may be more properly regarded as an abnormal and probably predominently parasympathetic response to stress rather than a failure to adjust, the emphasis on the "psychoneurotic" is in agreement with our conception of this reaction.

f. It is well-known (Gibbs and Gibbs,(3) for references) that there is no valid difference in the EEG's of normal and psychoneurotic individuals. It may well be that these reactors are, at least temporarily, psychoneurotic, and that twice-NCC cases are more likely to be disturbed than others. Motivation is of considerable importance in the processing of cadets through the chambers, and many of them consider it a test rather than an indoctrination technique. In one case, a cadet who collapsed after 5

minutes at 18,000 feet returned to volunteer, on his second flight, as an anoxic subject for a demonstration in which ascent is made to 26,000 feet without oxygen; he gave a quite normal performance.

g. There are no evident reasons for the differences between the present study and that of Baxter et al (4), other than the factor of random sampling in their selection of 10 cases. Studies are continuing at this Unit to increase the number of cases and make more valuable the statistical analysis of the results.

6. Summary and Conclusions:

a. Individuals suffering syncopal reactions (NCC) with unconsciousness at a simulated altitude of 18,000 feet in the altitude chambers were studied by electroencephalography.

b. Abnormal records were found in 7 (21.2%) of 33 individuals who collapsed once; in 5 (23.8%) of 21 individuals who collapsed twice; and in 3 (15%) of 20 controls.

c. Only 1 record (in an individual who later completed a flight sucessfully) was considered compatible with a diagnosis of epilepsy (petit mal variant). The other abnormal records were so considered because of excessive slow (6-7 per second) wave activity.

d. Only 4 of these men (two single and two double reactors) had convulsive movements as part of the NCC reaction; one of each group had abnormally slow brain waves.

e. Of 2 cadets who are known to have been diagnosed as epileptics while in training, both completed their altitude training at this Station without showing the NCC reaction.

f. It is felt that syncopal reactors (NCC) at 18,000 feet simulated altitude more probably represent a psychosomatic type of disorder than a basically epileptic disorder.

* * *

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## SIGNIFICANCE OF FIVE THOUSAND FOOT EAR CHECK IN ALTITUDE CHAMBER FLIGHTS

PURPOSE:

Letters AAF 353.01 and 50-28, Hq AAF, Washington, D.C., dated 17 July 1943, and 25 May 1944, titled, "Instructions Governing the Altitude Training Program," indicate that on all simulated flights the chambers, "ascend to 5000 feet and return to ground level for the purpose of demonstrating methods for clearing ears." In observing chamber flights over a period of months, it seemed to the writer that the 5000 feet ear-check was acting as an unnecessary source of trauma and aero-otitis and was serving no really instructive purpose. The following investigation was instituted to check the validity of this impression.

METHOD:

This Unit is equipped with two twenty (20) man Guardite chambers. These are designated as chambers "A" and "B". In all chamber flights presided over by the writer, chamber B followed the usual ear-check procedure of ascending to 5000 feet at a rate of about 1500-2000 ft per minute and then descending to ground level at a similar rate. In chamber A the 5000 ft ear-check was completely dispensed with. The trainees in almost all cases were pre-gunnery students of comparable age, housed largely in tent barracks and therefore subject to at least comparable degrees of upper respiratory infections with the expectant predisposition to aero-otitis. All trainees complaining of ear trouble were examined and classified according to degree of redness. In all cases objective evidence of hyperemia and aero-otitis was present. For the sake of simplicity, however, the degree of severity was not considered in this study. The procedure was carried through from October to August and therefore contains data in which seasonal variations may have played some part.

OBSERVATIONS:

Chamber "A" in all cases designates a flight in which an ear-check <u>was not</u> done.

Chamber "B" designates a flight in which a 5000 foor ear-check <u>was</u> accomplished according to existing directives.

Observations were made and data collected in a total of 100 separate chamber flights.

| | CHAMBER A | CHAMBER B |
|---|---|---|
| Total No. carried in 110 flights | 2218 | 2023 |
| Average No. carried on each flight | 20.16 | 18.39 |
| Total No. of individuals with ear trouble | 130 | 143 |
| Average ear trouble per flight | 1.18 | 1.30 |
| Percentage of trainees with ear trouble | 5.86 | 7.06 |

DISCUSSION:

Examination of our records reveals that for a 12 month period July 1943 to June 1944 of 22,389 trainees, 6.34% developed demonstrable ear trouble. It would seem therefore, that 6.34% could be used as an average figure of the incidence of aero-otitis in chamber flights. Comparison with the incidence in our series reveals a difference of 0.48% in Chamber A and 0.72% in Chamber B. These are so slight that it would seem that any difference noted between Chamber A and Chamber B is of no significance.

In 53 of the Chamber B flights the incidence of ear trouble "before" and "after" the 5000 ft ear-check was recorded. It was observed that there were 98 cases of ear trouble and of these 66 cases or 67.4% did not manifest themselves on the ear check but on the descent. It would, therefore, seem that the objective of the 5000 ft ear check to demonstrate how to clear the ears is not born out in actual flights.

SUMMARY:

A study was instituted to determine the effect of the ear-check on the development of aero-otitis. In a total of 110 chamber flights data was gathered by comparing one chamber in which a 5000 ft ear-check was not carried out. A further study was carried out in 53 chamber flights, to determine the incidence of aero-otitis "before" and "after" the 5000 ft ear-check.

CONCLUSION:

Aero-otitis was noted in 7.06% of those trainees having been subjected to a 5000 ft ear-check. An incidence of 5.86% was noted in the group in which an ear check was not carried out. Taking 6.34% as an average incidence for a large unselected population of trainees it may readily be seen that the incidence of aero-otitis with and without the ear-check approximates this average very closely and that the slight difference is of no statistical significance. It would, therefore, seem that the original premise, that the 5000 ft ear-check creates aero-otitis is not born out in actual experimental fact.

In the ear-check series, 67.4% had not complained after the ear-check but complained only on the descent at the completion of the flight. With an incidence of aero-otitis so high it would seem that the primary purpose of the ear-check, i.e. "demonstrating methods of clearing ears," is not fulfilled.

In conclusion this study has revealed that the incidence of aero-otitis is unaffected whether or not a 5000 ft ear-check is carried out. It is further observed that a majority of cases manifest aero-otitis on the descent at the completion of the flight and not after the ear-check. The value of the 5000 ft ear-check as a method for

instructing trainees how to clear their ears is therefore questioned. It is felt much time and effort could be saved by abolishing this procedure.

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* * *

## NOTES ON THE OCCURRENCE OF DECOMPRESSION SICKNESS ON DESCENT FROM HIGH ALTITUDES

### 1. Introduction

While the symptoms of decompression sickness usually occur during a stay at altitudes above 30,000 feet, it is of interest to note that occasionally chokes and neurological disturbances may occur <u>during or after descent</u>, at altitudes at which bends and chokes ordinarily disappear. The following report and analysis was prepared in an attempt to gain a better understanding of these paradoxical symptoms.

Fourteen cases of such unusual reactions were observed during routine chamber flights at the Fifth Altitude Training Unit, Davis-Monthan Field, Tucson, Arizona (elevation 2500 feet).

### 2. The occurrence of paradoxical chokes during descent

Six cases in which the paradoxical occurrence of chokes during descent from simulated high altitudes were observed, and these are described in table 1. None of these individuals exhibited any sign of chokes during ascent and sojourn at altitude, the symptoms of chokes appearing for the first time during descent.

Table 1

| Case | Symptoms at 38,000 feet | Symptoms during descent | Altitude of onset during descent, feet | Duration of symptoms, minutes |
|---|---|---|---|---|
| 1. | Bends: Left Knee | Substernal burning | 30,000 | 15 |
| 2. | Bends: L. Hand<br>L. Elbow<br>L. Shoulder | Substernal burning | 25,000 | Several hours |
| 3. | Bends: L. Knee<br>R. Ankle<br>R. Knee | Severe substernal aching and burning, Cough | 34,000 while straining | 60 |

| | | | |
|---|---|---|---|
| 4. Bends: R. Knee<br>R. Calf | Substernal burning, severest during expiration, nausea | 27,000 | 10 |
| 5. Bends: L. Ankle<br>L. Knee | Substernal burning, severest during expiration | 24,000 | 15 |
| 6. Bends: L. Shoulder<br>R. Shoulder<br>L. Knee | Sharp stabbing pain substernal and on left side; dyspnea, "numb all over" | 28,000 | 60 |

Cases 1 to 4 were members of the regular low pressure chamber crew, who had experienced chokes on previous flights. Case 6 gave a history of pleurisy in childhood.

3. The occurrence of neurological disturbances during or after descent.

During simulated high altitude flights transient neurological disturbances occur not uncommonly. These include scotomata with blurring of vision, paralyses, aphasias, vomiting, profuse sweating and severe headaches. The fact that these symptoms may occur during or after descent at altitudes at which bends and chokes usually disappear, makes such conditions of special interest. Eight cases are reported in table 2.

Table 2

| Case | Symptoms at 38,000 feet | Symptoms during or after descent | Altitude of onset during descent, feet | Duration Symptoms, minutes |
|---|---|---|---|---|
| 7. | Severe chokes | Vomiting, severe headache | Ground level | 12 hours |
| 8. | Mild chokes<br>Bends: L. Ankle<br>L. Leg | Blurring of vision | 10,000 | 1 hour |
| 9. | Abdominal pain | Blurring of vision | 30,000 | ½ hour |
| 10. | Bends: L. Shoulder<br>R. Arm | Blurring of vision, profuse sweating, faintness | 30,000 | 1 hour |
| 11. | Bends: L. Ankle<br>L. Shoulder<br>L. Elbow | Nausea, markedly constricted field of vision, profuse sweating | 20,000 | 1 hour |

| | | | | |
|---|---|---|---|---|
| 12. | Bends: R. Ankle<br>L. Knee<br>Coughing | Blurring of vision | Ground level | 1 hour |
| 13. | Bends: R. Hand<br>R. Shoulder | Blurring of vision | 10 min. at<br>Ground level | ½ hour |
| 14. | Bends: R. Knee<br>Chokes | Blurring of vision | Ground level | 1 hour |

These neurological disturbances were usually followed in 10 to 30 minutes by a severe intractible headache which commonly persisted for 1 hour, and in one case for as long as 12 hours.

4. <u>Discussion</u>.

Decompression sickness at altitude is believed by some workers (1) to be due to the formation and growth of bubbles in the body during the stay at high altitudes. This interpretation may also be used to explain the paradoxical occurrence of decompression sickness during descent.

Thus, at high altitudes intravascular bubbles may act as emboli in the circulatory system. During descent, these bubbles would be reduced in size because of the increased barometric pressure, and also because of the increased tendency for the gases in the bubble to redissolve. When the bubble is sufficiently reduced in size so that it no longer obstructs the blood vessel at a given point, it could pass along the blood stream to produce an obstruction in a vessel of smaller calibre.

In cases with bends, the reduction in size of bubble <u>during descent</u> may be adequate to dislodge these bubbles from their original location in the extremities and allow such bubbles to pass to the lungs. Acting as aeroemboli in the pulmonary arterioles and capillaries, they may produce "paradoxical chokes". In this regard it is of interest to note that all six individuals who developed paradoxical chokes had experienced bends previously during the stay at 38,000 feet, and that the bends disappeared during descent shortly before the onset of chokes.

Since the symptoms of paradoxical chokes may be mild and usually disappear upon further descent, they may not always be reported. Perhaps for this reason case reports and discussion of this interesting syndrome have not previously appeared.

Neurological disturbances occur most frequently in subjects who had experienced bends and chokes during the stay at high altitudes (2,3,4,5). In these cases the bubbles might be in the extremities where they manifest themselves in symptoms of bends, or perhaps in the pulmonary arterioles and capillaries where they act to produce symptoms of chokes. Reduction in the size of these bubbles during descent might allow their passage through the pulmonary blood vessels to the systemic circulation. If these passed as emboli to the brain or spinal cord, they might conceivably produce neurological

disturbances depending on the region affected. Delayed freeing of the bubbles would result in delayed symptomatology.

The occasional occurrence of blurring of vision and other neurological disturbances after a coughing spell while at 38,000 feet has also been observed. It is possible that coughing may act in a way similar to that described above to produce neurological disturbances while remaining at high altitude. The intrathoracic pressure may be increased by coughing or straining as much as 100 mm. Hg, equivalent to a momentary descent of the thoracic tissues from 38,000 to about 28,000 feet.

It would appear, then, that the symptoms of paradoxical chokes and neurological disturbances may frequently be more properly ascribed to re-compression rather than de-compression.

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ASSAY OF OXYGEN IN CYLINDERS DELIVERED FOR USE IN LOW PRESSURE CHAMBERS.

Prior to use in the low pressure chamber all oxygen cylinders are tested for the possibility of having been filled wholly or in part with gases other than oxygen. A sample is collected from each cylinder into a A8B mask rebreather bag via a style G check valve (part # 43A9036) inserted in the wide end. A 6" length of aluminum tubing (5/16" O.D.) is connected to the constricted (tubing) end of the rebreather bag, the flattened end of the former allowing a fine stream of gas to come from the bag as it is squeezed. On the basis of physical properties considerable differentiation can be made. Oxygen, carbon dioxide, carbon monoxide, helium and hydrogen are colorless, odorless and tasteless; acetylene and nitrous oxide have their own characteristic odors. When subjected to the flame test, these gases may be separated further into the incombustible group ($CO_2$ and He), those that cause a glowing splinter of wood to burst into

flame ($O_2$ and $N_2O$), those that burn (CO, with a bluish flame; $C_2H_2$ with an intensely luminous flame), and the highly explosive $H_2$.

Quantitative analysis of the sample of "pure oxygen" is carried out as follows: The bulb of a Scholander burette is filled with 1" lengths of spring made from 18 gauge copper wire coiled around a 1/4" rod. The burette is then filled with the ammonia-ammonium chloride reagent of Badger*, consisting of an ammonium chloride-saturated 1:1 mixture of concentrated ammonium hydroxide (27% $NH_3$) and distilled water. A second analyzer is filled with 10% KOH, and both reagent levels are covered with a petrolatum oil seal. Samples (5 cc.) of the gas are injected into the rubber tubing of each burette, and the latter are shaken a few times to enable complete solution. The cu-ammonia-ammonium chloride reagent can absorb 50 to 60 times its volume of oxygen, the mechanism of the reaction being the oxidation of the copper, subsequent solution of the oxide leaving fresh and active copper surfaces for further oxidation, and the formation of hydrated ammonium-cupric chloride which imparts a blue color to the solution. The reagent is inexpensive and readily prepared from common chemicals, is active at almost any temperature and has the advantage* of giving a qualitative test for oxygen (blue color) while the quantitative analysis is in progress. It is also more convenient to use, provides a clear and easily read meniscus, and has long life. Complete assay of a sample may be made in two minutes. On the basis of the foregoing, the advantages over pyrogallate are many.

A colorless, odorless, tasteless gas which does not burn but causes a glowing splinter of wood to burst into flame, which imparts a blue color to the solution and is more than 99% absorbed by the Cu-ammonia-ammonium chloride reagent*, and which is not absorbed by KOH can be nothing other than pure oxygen and may be safely used in the low pressure chamber.

Summary:

A procedure is described for checking the contents of oxygen cylinders. Gases other than oxygen may be differentiated and eliminated on the basis of physical properties, including response to the flame test. The oxygen is quantitatively assayed in a Scholander burette containing a copper-ammonia-ammonium chloride reagent. The presence and amount of carbon dioxide is determined with a second burette containing KOH. The entire procedure is simple, convenient, rapid and accurate. The equipment and materials required are already available at Altitude Training Units.

EDWARD EAGLE, Capt., Air Corps
29th Altitude Training Unit
San Antonio Aviation Cadet Center
San Antonio, Texas

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* Badger, W. L., J. Ind. Eng. Chem. 12: 161 (1920); U.S.P. XII, p. 344.

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THREE ACCESSORY DEVICES USED IN TEACHING OXYGEN
EQUIPMENT AND THE DANGERS OF ANOXIA AT THE
UNITED STATES NAVAL AIR STATION, MIAMI, FLORIDA

Since Altitude Training Units exist primarily for the instruction of aviation personnel, the more closely flight conditions are simulated in Low Pressure Chambers, the more effective will be the instruction. With this in mind three devices are reported here which have proven of value in this unit.

The function of this oxygen equipment will be much more practical to the pilot and aircrewman if, after the lecture and demonstration on equipment, and after the chamber run, he can actually see the equipment in the type plane he expects to fly. This is of course always done on the flight line before the first oxygen flight, but it is of particular value at the time of his oxygen indoctrination.

We were able to obtain a non-salvagable TBM fuselage, the result of a salt water crash, and this is located immediately adjacent to the Low Pressure Chamber Unit. The body was thoroughly cleaned and stripped, the wings were removed, and a ladder and ramp built to the wing stubs. Rebreather oxygen equipment was installed and all oxygen lines painted a bright green. Each pilot and aircrewman who will fly in the TBF or TBM is checked out in this fuselage before his oxygen indoctrination is completed. This check-out consolidates the theory of oxygen equipment with actual contact in the plane at the time he is given his most extensive instruction in equipment.

To demonstrate the insidious nature of anoxia at high altitudes, it is our practice to have a volunteer remove his oxygen mask at 30,000 feet. A gun mount from the rear seat of a TBD was removed and installed in the chamber so as to give free rotation of the seat and for a surveyed aircraft machine gun mounted on the ring. The gun trigger was wired to a small flashlight battery and bulb.

After complete instructions and a few trial runs, the subject removes his oxygen mask, planning to replace it himself before it is too late. The head observer then calls out the names of aircraft locating them over various seats in the chamber. The volunteer is instructed to point and wave to friendly planes, but to aim at and "shoot down" enemy planes. His co-ordination begins to falter after 40-50 seconds; he swings the gun more clumsily. Then he waves to the foe, and shoots at his allies, growing more and more inco-ordinated. Finally he is helpless, waves blindly, or shoots steadily with no thought to his problem. At this stage we ask him to replace his mask himself for he has completely forgotten it. Seldom is he able to do so without the assistance of the inside observer. The mild muscular exertion required to swing the gun, plus the distraction of the problem leaves little room for thought of oxygen. Less than a third of the men have been able to replace their masks without assistance.

It requires little imagination on the part of the other passengers to picture this pilot or gunner, helplessly anoxic in his seat, a menace to his friends and a "dead duck" to the enemy.

Since the actual removal of the mask would be an unusual occurence in aircraft at high altitudes, we have tried to simulate other accidents which might arise to cause severe anoxia. Disconnecting the breathing tube from the regulater, or jamming the exhalation valves in the demand type mask gave only moderate success. The most practicable arrangement has been a small hole cut in the re-enforced rubber tubing close to the regulater, comparable to a bullet hole. This is normally covered with a rubber or metal ring which can be easily slipped down to open the hole without attracting the attention of the subject.

Sometimes we warn all passengers that one of them has had his equipment damaged and must be on the alert to detect anoxia. The instruction is probably more effective without warning, and it is gratifying to watch the individual concerned as he detects anoxia and turns on his emergency. After he has appreciated his danger, and the majority are able to do so in time, he is shown its cause, and the chances of a similar accident occurring in a plane as the result of enemy action are pointed out to all passengers.

* * *

TREND OF ANOXIA ACCIDENTS
IN THE EIGHTH AIR FORCE
HEAVY BOMBARDMENT

Oct. 1943 - Nov. 1944

| | Accidents | | Fatalities | |
|---|---|---|---|---|
| | Rate per 100,000 Man-Missions | Rate per 100,000 Hrs in Combat | Rate per 100,000 Man-Missions | Rate per 100,000 Hrs in Combat |
| Oct 1943 | - | - | 18.0 | 2.70 |
| Nov | 115.5 | 17.7 | 21.6 | 3.33 |
| Dec | 63.6 | 9.4 | 15.0 | 2.24 |
| Jan 1944 | 34.5 | 6.0 | 4.7 | .60 |
| Feb. | 50.5 | 7.8 | 1.0 | .15 |
| Mar | 18.1 | 2.6 | 3.4 | .49 |
| Apr | 0.5 | 0.8 | 0.6 | .11 |
| May | 16.6 | 2.7 | 0.5 | .08 |

| | | | | |
|---|---|---|---|---|
| Jun | 6.2 | 1.1 | 0.6 | .12 |
| Jul | 6.7 | 0.9 | 1.8 | .26 |
| Aug | 6.9 | 1.0 | 1.7 | .14 |
| Sep | 11.8 | 1.7 | 4.1 | .61 |
| Oct | 16.1 | 2.4 | 1.7 | .25 |
| Nov | 23.4 | 3.3 | 7.1 | 1.0 |

* * *

Accidents due to Anoxia (Incomplete Reports)
October 1944

44 accidents including 6 deaths

| | TG | TTG | BTG | WG | N | RO | B | NTG | P | Co-P | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Causes | | | | | | | | | | | |
| Faults in Equipment | | | | | | | | | | | |
| Ice in mask or hose | 2 | | 4* | | 1 | | 1 | 2 | | | 10 (1)* |
| Hose disconnected | 5 (2)* | 2 | 2 | 2 | | | | | | 1 | 12 (2)* |
| Defective oxyg. system | 1 | 1 | 3 | 3 | 1 | 1 | | | 1 | 1 | 11 |
| Loose connection | | | 1 | | | | | | | | 1 |
| Personal | | | | | | | | | | | |
| Removal of mask | 1* | | 1 | 1 | | | | | | | 3 (1)* |
| Vomiting | 1 | | | | | | | | | | 1 |
| Unconscious | | | 1 | | | | | | | | 1 |
| Combat | | | | | | | | | | | |
| Oxygen system shot away | | | 1 | | | | | | | | 1 |
| Others | | | | | | | | | | | |
| Unknown | 1* | | 1 | | | | 1 | | 1* | | 4 (2)* |
| TOTAL | 11 | 3 | 13 | 6 | 2 | 1 | 2 | 2 | 2 | 2 | 44 (6)* |

* Indicates one fatality unless otherwise specified by numbers in brackets.

SUMMARY

| | TG | TTG | BTG | WG | N | RO | B | NTG | P | Co-P | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Causes | | | | | | | | | | | |
| Equipment | 8 | 3 | 9 | 5 | 2 | 1 | 1 | 2 | 1 | 2 | 34 (3)* |
| Personal | 2 | | 2 | 1 | | | | | | | 5 (1)* |
| Combat | | | 1 | | | | | | | | 1 |
| Others | 1 | | 1 | | | | 1 | | 1 | | 4 (2)* |
| TOTAL | 11 | 3 | 13 | 6 | 2 | 1 | 2 | 2 | 2 | 2 | 44 (6)* |

* indicates one fatality unless otherwise specified by numbers in brackets.

TG - Tail Gunner
TTG - Top Turret Gunner or Engineer
BTG - Ball Turret Gunner
WG - Waist Gunner
N - Navigator
RO - Radio Operator
B - Bombardier
NTG - Nose Turret Gunner
P - Pilot
Co-P- Co-Pilot
YO - Y Operator

Accidents due to Anoxia (Incomplete Reports)
November 1944

54 accidents including 18 deaths

| | TG | TTG | BTG | WG | N | RO | B | NTG | P | YO | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Causes | | | | | | | | | | | |
| Faults in Equipment | | | | | | | | | | | |
| Ice in Mask | 2* | | 2* | 2* | 2* | | 1 | 1 | | | 10 (4)* |
| Hose disconnected | 5 (4)* | | 3 | 2 | 3* | 4* | 1 | | | 1* | 19 (7)* |
| Mask fit | | | 1 | | | | | | | | 1 |
| Pressure gauge | | | | 1* | | | | | | | 1 (1)* |
| Walk around supply | 1 | 1 | | | | | | | | | 2 |
| Kink in walk around hose | | | | 1 | | | | | | | 1 |
| Leak in oxyg. sys. | | 1 | | | | | | | | | 1 |
| Loose connection | | 1 | | | | | | | | | 1 |
| Personal | | | | | | | | | | | |
| Unconscious when alt. reached | 1* | | | | | | | | | | 1 (1)* |

| (Cont'd) | TG | TTG | BTG | WG | N | RO | B | NTG | P | YO | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Vomiting | 1 | | | | | | | 1 | | | 2 |
| Hose caught on turret handle | | 1* | | | | | | | | | 1 (1)* |
| Interchanged micro. for mask | | | | | 1 | | | | | | 1 |
| Ignorance re valves to top turret | | 2 | | | | | | | | | 2 |
| Poor oxygen procedure | | | 1 | | | | | | | | 1 |
| Failure to reconnect mask | | | | | | 1 | | | | | 1 |
| Combat | | | | | | | | | | | |
| Oxyg. system shot away | 1* | 1 | 1 | 1 | | | | | | | 4 (1)* |
| Others | | | | | | | | | | | |
| Carbon monoxide | | | | | | | | | 1* | | 1 (1)* |
| Perforation of hose by object on ship | | | | | | 1 | | | | | 1 |
| Unknown | 1 | 1* | | 1* | | | | | | | 3 (2)* |
| TOTAL | 12 | 8 | 8 | 8 | 6 | 6 | 2 | 2 | 1 | 1 | 54 (18)* |

SUMMARY

| | TG | TTG | BTG | WG | N | RO | B | NTG | P | YO | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Causes | | | | | | | | | | | |
| Equipment | 8 | 3 | 6 | 6 | 5 | 4 | 2 | 1 | | 1 | 36 (12)* |
| Personal | 2 | 3 | 1 | | 1 | 1 | | 1 | | | 9 (2)* |
| Combat | 1 | 1 | 1 | 1 | | | | | | | 4 (1)* |
| Others | 1 | 1 | | 1 | | 1 | | | 1 | | 5 (3)* |
| TOTAL | 12 | 8 | 8 | 8 | 6 | 6 | 2 | 2 | 1 | 1 | 54 (18)* |

* Indicates one fatality unless otherwise specified by numbers in brackets.

## ANOXIA REPORT FROM 15TH AIR FORCE

On 13 September 1944, after having just gone over the target at an altitude of approximately 28,500 feet, through moderate and intense flak, the tail gunner called over the interphone that he was in trouble with his oxygen. The radio operator, using a walk around bottle with a pressure of 380 p.s.i., crawled back to the tail gunner and then returned to the waist whereupon he sank down unconscious. The left waist gunner, S/Sgt. Bernard P. Deppe, revived T/Sgt George H. Burgess, the radio operator by hooking his walk around bottle to the refill. Burgess immediately recovered and motioned Deppe to go back to the tail and take care of the tail gunner, S/Sgt. Charles H. Hill. Deppe crawled to the rear using a walk-around bottle filled at 150 lbs, (it had been used previously during the mission) and found Hill in a slumped position against his guns, his eyes rolled upward in a glassy stare and bloody foam drooling from his mouth. He also found that the oxygen blinker was not moving, the tail gunner's mask was off his face, and there was a cut through one half the circumference of the hose to the oxygen mask. This rent in the hose had the appearance of having been cut by something as sharp as a razor.

Seeing that another oxygen mask was needed to revive the tail gunner, Deppe crawled back and got only as far as the wheel well when he lost consciousness. Radio operator Burgess realized Deppe's trouble, secured a large emergency oxygen bottle (filled at 450 p.s.i.) from the radio room and immediately revived Deppe, then Deppe, after getting a new oxygen mask, crawled back to the tail gunner, carrying his large oxygen bottle with him and for one hour held the mask to the tail gunner's face, rocking him back and forth the best he could in an attempt to rescuscitate him. The tail gunner was sitting on his stool with his legs propped backwards. Deppe found he could not extricate him alone. He became so tired and weak in the attempt to revive the tail gunner that he involuntarily urinated.

After reaching 16,000 feet, Deppe called for help and was relieved by the engineer, T/Sgt. Fields, and the ball turret gunner, S/Sgt. Anderson. Deppe then crawled to the waist, exhausted, and sucked on pure oxygen.

Fields and Anderson removed the tail gunner to the wheel well, laying him flat with blanket coverings. At this time the tail gunner was beginning to breathe spontaneously, and a large oxygen bottle was connected to his mask. After some fifteen minutes he was removed to the radio room where his electric suit was plugged in. He soon began to flail his arms about like a wild man, but these movements ceased with gentle restraint.

It wasn't until ½ hour before landing that Hill opened his eyes. When loaded into the ambulance he was breathing regularly. His mind was hazy and he apparently realized little of what was going on.

Deppe searched the tail region for flak holes and finally found a small hole, about 3 mm in diameter in the right bottom side in front of the tail gunner's seat. No pieces of flak were found.

It is our belief that S/Sgt. Hill was brought from the very jaws of death, thanks to the fortitude of Sgt. Deppe.

R. J. BEAL, Major, Medical Corps
Group Flight Surgeon
Bombardment Group (H)

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## RELATIVE EASE OF FITTING OXYGEN MASKS

Lieutenant Frederick N. Zeiner, Altitude Indoctrination Unit, Lincoln Army Air Field, reports that on the basis of approximately 4,000 mask fits, the A-14 mask can be satisfactorily fitted more readily than can the A-10A mask. Of those men fitted with A-10A masks, 6.31 per cent experienced difficulty with their masks; in contrast, only 1.71 per cent of those fitted with A-14 masks complained of an unsatisfactory fit.

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AVIATION PHYSIOLOGISTS BULLETIN

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## 1943-44



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